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Mono Slab EZ Form
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Frost-Protected Shallow Foundations

Shallow foundations for construction projects are very desirable in controlling installation costs for slab-on-grade construction. In colder climates, frost will penetrate under unprotected foundations and cause damage to the building structure and floor slab. It is imperative that shallow foundations are properly protected from frost to eliminate potential frost damage to the building. The purpose of this report is to illustrate how Mono Slab EZ Forms meet building code requirements for insulating frost-protected shallow foundations. The focus of the report is the insulation properties and performance of Mono Slab EZ Forms. All code requirements for frost-protected shallow foundations must be adhered to and are not specifically referenced in this report.

Mono Slab EZ Forms

The Mono Slab EZ Forms are currently fabricated in three size forms: Standard, Arctic, and Commercial. The forms allow the installer to form footings, foundations, and on-grade floor for a single concrete pour. The forms are constructed of expanded polystyrene (EPS) that offers excellent insulation properties enabling the form to double as the code required insulation for the frost-protected shallow foundation.

Governing Code

Many jurisdictions across the United States and Internationally utilize the International Code Council (ICC) suite of codes. The International Residential Code (IRC) and the International Building Code (IBC) are part of the ICC codes. Chapter 4 of the IRC governs the design and installation of residential building foundations. Chapter 18 of the IBC governs the design and installation of non-residential or commercial building foundations. Both codes require that all foundations are protected from frost. Section R403.1.4.1 of the 2012, 2015, and 2018 IRC lists (4) methods for providing frost protection and section 1809.5 of the 2012, 2015, and 2018 IBC lists (3) methods for providing foundation frost protection. One or more of the listed methods may be followed. “Constructed in accordance with ASCE 32” is a method listed in the IRC and the IBC. “Constructed in accordance with Section R403.3” is also an acceptable method found in the IRC. Mono Slab EZ Forms meet requirements included in both acceptable methods.

Heated Residential Buildings

Section R403.3 of the IRC includes requirements for frost-protected shallow foundations for residential buildings or portions of residential buildings that are maintained at not less than 64°F. Figure R403.3(1) and Table R403.3(1) of the IRC present insulation requirements for frost-protected shallow foundations based on the Air Freezing Index (AFI) of the building location. Insulation is required to limit the heat transferred from the heated building and the ground core temperature to the outdoors. Table R403.3(1) includes requirements for vertical and horizontal insulation dimensions and performance (R-value).

Vertical Insulation

Expanded polystyrene (EPS) is a very good insulation material and is widely used in frost-protected shallow foundation applications. Table R403.3(1) of the IRC lists vertical and horizontal R-values for various types of EPS. The vertical and horizontal R-values differ from each other and are less than the rated R-value of the insulation to account for degradation over time of the below grade insulation. These values are based on laboratory and field test data performed and collected by American Society of Civil Engineers (ASCE). The Mono Slab EZ Forms are Type I EPS and R-value data is not included in Table R403.3(1). An ICC evaluation agency has reviewed the installation and performance of the Mono Slab EZ Forms. This agency issued a report indicating that the forms meet the requirements of the IRC. This report is titled ESR-4106 and may be obtained by contacting Mono Slab EZ Form.

The ESR-4106 report includes a rated R-value of 3.6 per inch for the Mono Slab EZ Forms and a vertical R-value of 2.8 per inch to use in conjunction with Table R403.3(1). As illustrated in Table 1, all three Mono Slab EZ Forms exceed minimum R-value code requirements for vertical insulation assuming R-2.8 per inch. The depth below grade requirements listed in Table R403.3(1) must be addressed based on the selected form, exterior wall type, finished grade, etc. Mono Slab EZ Form may supply installation details for various applications.

AFI	Vertical R-Value	
	Required	Standard, Arctic, and Commercial Mono Slab EZ Forms
1500	4.5	6.3
2000	5.6	6.3
2500	6.7	10.5 ¹
3000	7.8	10.5 ¹
3500	9.0	10.5 ¹
4000	10.1	10.5 ¹

1. R-value includes insert.

Table 1: Vertical R-Value Compliance

Horizontal Insulation

The ESR-4106 report also lists a horizontal R-value per inch of 1.3 for Type I EPS. This reduction in horizontal R-value is based on projections and assumptions of how well the insulation will perform below grade over time. The assumption is the insulation will degrade over time from R-3.6 to R-1.3 per inch. We believe that the Mono Slab EZ Forms will perform much better than the R-1.3 indicated in the report for several reasons.

The published study [Below Ground Performance of Rigid Polystyrene Foam Insulation: Review of Effective Resistivity Values Used in ASCE 32-01 – Design and Construction of Frost-Protected Shallow Foundations](#) (Crandell-2010) provides a summary of the studies that were used to determine the vertical and horizontal R-values for the various EPS and XPS insulation materials for the ASCE 32 standard. The insulation requirements presented in IRC 403.3 match the ASCE 32 standard requirements. Based on the studies cited by Crandell of Type I EPS, he recommended applying a horizontal R-value of 2.1 per inch for Type I EPS in below grade applications.

Crandell notes that degradation over time is due primarily to moisture. The Mono Slab EZ Forms have a wedge shape that forces moisture to drain from the form much more effectively than flat insulation materials. Also, the Mono Slab EZ Forms are much thicker overall than the standard flat insulation materials which provides greater protection over time from wet soil conditions.

The horizontal R-value of 1.3 as listed in ESR-4106 is 36% of the rated R-value of 3.6. The horizontal R-value of Type II EPS listed in Table R403.3(1) is approximately 65% of the EPS rated R-value. We do not believe that the horizontal R-value of 1.3 per inch listed in ESR-4106 is realistic compared to many other reference points as presented. Our calculations presented in this report assume a horizontal R-value of 1.8 per inch. This horizontal R-value is 50% of the rated R-value and less than the horizontal R-value of 2.1 recommended by Crandell. The Mono Slab EZ Forms will perform at a higher level than traditional flat Type I insulation products.

As mentioned previously, the purpose of the below grade insulation is to limit the heat transfer to the outdoors and avoid freezing soils at the foundation and footing locations. Overall heat transfer is dependent on the insulation R-value. Each Mono Slab EZ Form has an overall horizontal R-value that takes in to account the entire shape of the form. This overall R-value is similar to the overall R-value of an insulated wood stud wall. In an insulated stud wall, heat transfer occurs at different rates depending on the heat transfer path. Heat moves very slowly through the insulation and very quickly through the wood studs. The speed of the heat transfer is dependent on the R-value of each heat transfer path. All heat transfer paths can be accounted for in an overall R-value for the wall. This overall R-value is calculated using the Parallel Path Heat Flow Method found in 2017 ASHRAE Fundamentals:

$$U_{Overall} = (A_1 * U_1) + (A_2 * U_2) + \dots + (A_N * U_N)$$

$$\text{Where: } A = \text{Fractional Area} \ \& \ U = \frac{1}{R - \text{value}}$$

Equation 1: Parallel Path Heat Flow Method

Mono Slab EZ Form	Horizontal Overall R-Value
Artic	12.58
Standard	11.05
Commercial	16.21

Table 2: Overall R-value based on 1.8 per inch R-value

A 2” x 6” wood stud wall with R-19 batt insulation has an overall R-value of 13 even though the insulation is R-19 after taking in to account the heat paths through the insulation and wood studs. In similar fashion, an overall horizontal R-value is calculated for each Mono Slab EZ Form. Each heat transfer path is accounted for in Equation 1 to find the overall R-value ($1 / U$). Since the incremental R-value changes based on the shape of the form, one-inch wide vertical heat transfer paths are assumed for the wedge-shaped area of the form to account for varying R-values in Equation 1 as indicated in Figure 1 (R_N). The overall horizontal R-values for each form are found in Table 2. The calculations including the incremental R-values for each form are included in Appendix A.

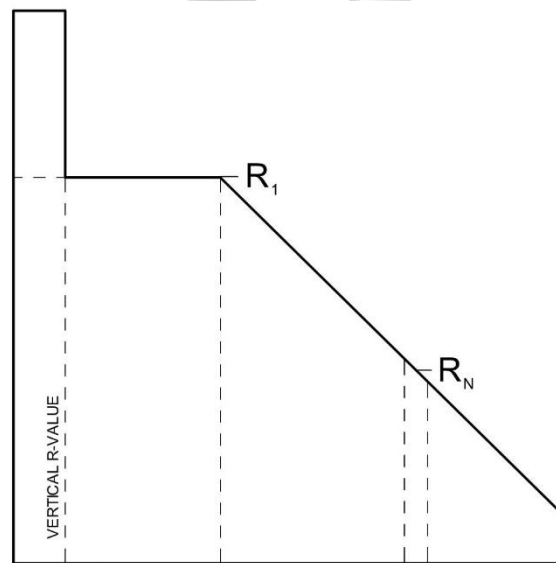


Figure 1: Mono Slab EZ Form indicating varying R-values based on thickness of the form.

A computational two-dimensional heat transfer model was created to investigate the performance of the Commercial Monoslab EZ Form compared to a conventional insulation application. The overall R-value for the Commercial Monoslab EZ Form was 16.21 in the model and the conventional insulation was the same width as the Commercial Form and 9” high to provide an R-16.21 at R-1.8 per inch. Model results are included in Figures 2 and 3 and in larger format in the Appendix. The temperature of the soil at the footing location (bottom left corner) is higher for the Commercial Monoslab EZ Form than for the conventional insulation with the same overall R-value and width. The overall R-value for the Mono Slab EZ Forms, as discussed, is an accurate representation of the heat transfer characteristics of the form and align well with code required R-values.

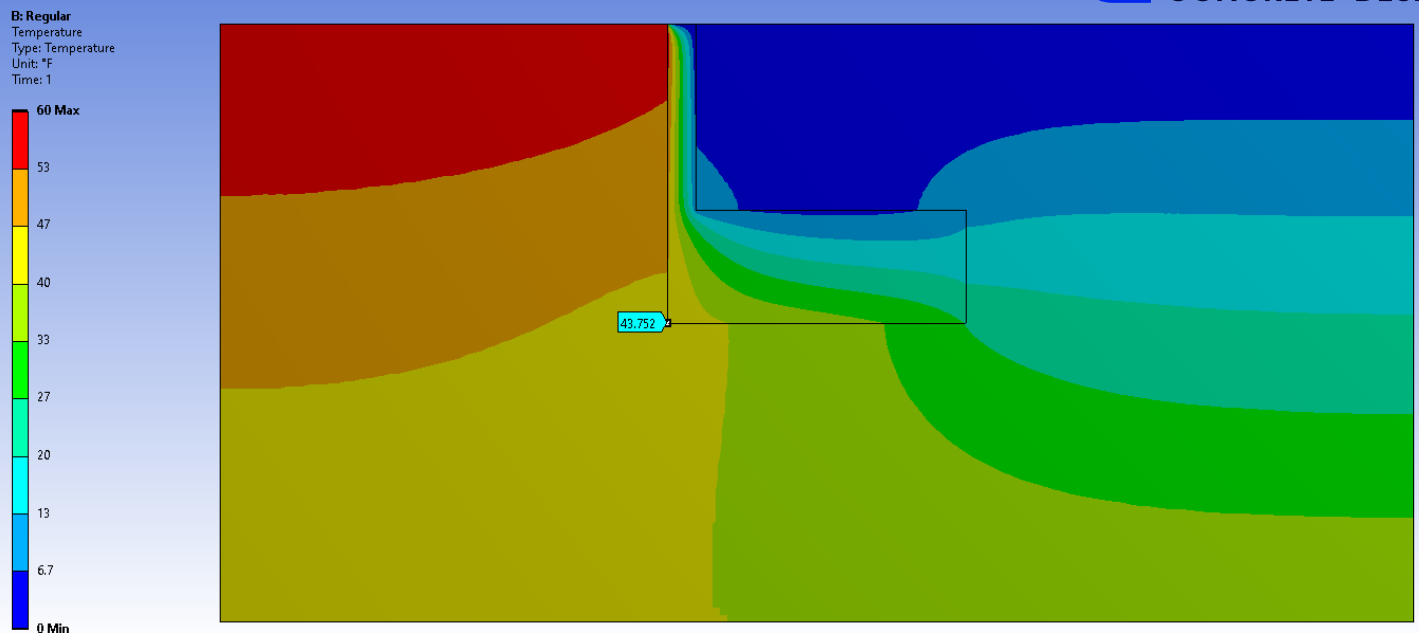


Figure 2: Computational heat transfer model results for conventional R-16.21 below grade insulation.

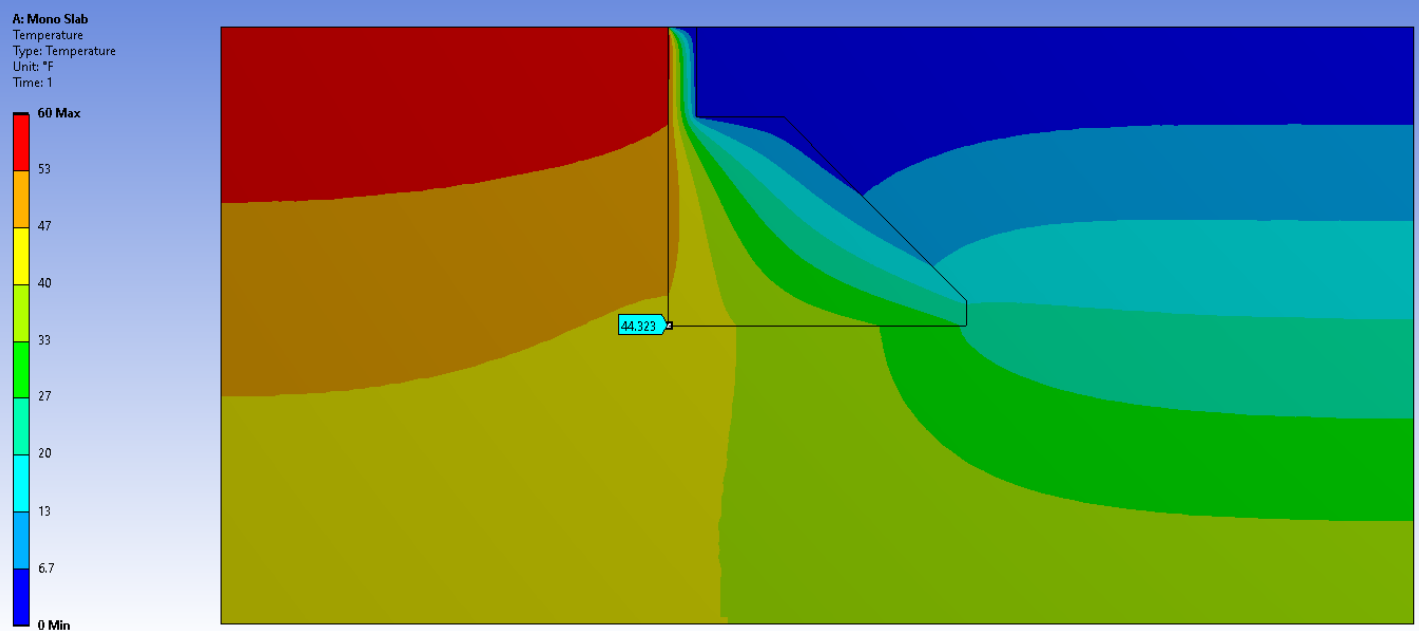


Figure 3: Computational heat transfer model results for Commercial Monoslab EZ Form with overall R-16.21.

Table 3 includes requirements from IRC 403.3 for horizontal insulation compared to actual insulation values for the Mono Slab EZ Forms. The gray cells indicate forms that require additional insulation to meet AFI specific code requirements. All “additional insulation” must meet requirements listed in the footnotes of Table R403.3(1). The blue cells indicate forms that meet AFI specific code requirements without additional insulation. For example, a Commercial Mono Slab EZ Form can be used in a location with a maximum 3,000 AFI without any additional horizontal insulation requirements. Installation details are available from Mono Slab EZ Form for various applications of horizontal insulation.

For a few cases the overall R-value of the forms do not meet minimum R-value code requirements (“At Corners”: Standard at 4000 AFI, Arctic at 4000 AFI). In these situations, additional insulation is required, and the starting location of that insulation should be the location of the form where the incremental R-value is greater than the code minimum requirement. This location is indicated in Table 3 in the “Width” column for these two scenarios.

Horizontal Insulation Along Walls											
AFI	Required		Standard Mono-slab			Arctic Mono-slab			Commercial Mono-slab		
	Width A	Horizontal R-value	Width	R-value	Additional Insulation	Width	R-value	Additional Insulation	Width	R-value	Additional Insulation
1500	NR	NR	16	11.1	NR	30	12.6	NR	24	16.2	NR
2000	NR	NR	16	11.1	NR	30	12.6	NR	24	16.2	NR
2500	12	1.7	16	11.1	NR	30	12.6	NR	24	16.2	NR
3000	12	6.5	16	11.1	NR	30	12.6	NR	24	16.2	NR
3500	24	8.0	16	11.1	8"	30	12.6	NR	24	16.2	NR
4000	24	10.5	16	11.1	8"	30	12.6	NR	24	16.2	NR

Horizontal Insulation At Corners											
AFI	Required		Standard Mono-slab			Arctic Mono-slab			Commercial Mono-slab		
	Width B	Horizontal R-value	Width	R-value	Additional Insulation	Width	R-value	Additional Insulation	Width	R-value	Additional Insulation
1500	NR	NR	16	11.1	NR	30	12.6	NR	24	16.2	NR
2000	NR	NR	16	11.1	NR	30	12.6	NR	24	16.2	NR
2500	24	4.9	16	11.1	8"	30	12.6	NR	24	16.2	NR
3000	24	8.6	16	11.1	8"	30	12.6	NR	24	16.2	NR
3500	30	11.2	16	11.1	14"	30	12.6	NR	24	16.2	6"
4000	36	13.1	10	14.1	26"	21	13.5	15"	24	16.2	12"

Table 3: Insulation requirements for AFI regions compared to Monoslab EZ Form performance

ASCE 32 also includes additional methods for heated buildings that address various applications. The tables discussed and presented from IRC 403.3 are based on the tables found in section 5 of ASCE 32. All information presented in this section also applies to ASCE 32.

Unheated Buildings

American Society of Civil Engineers Design and Construction of Frost-Protected Shallow Foundations (ASCE 32) was developed based on years of analysis and testing of freeze-protected shallow footings. ASCE 32 includes design methods for heated buildings, unheated buildings, and special conditions.

Section 7 of ASCE 32 specifies a method for unheated buildings with slab-on-ground foundations such as a garage. The insulation requirements are based on the AFI of the construction region, like the heated building method. The mean annual temperature (MAT) is also required and is included in ASCE 32 in map or table format as well as in NOAA - National Climatic Data Center.

The Mono Slab Forms demonstrate compliance for unheated buildings in a similar fashion as in heated buildings. To illustrate how the Mono Slab forms are applied to unheated buildings, an unheated building is reviewed for a location with an approximate AFI of 2,250 and a MAT of 41°F. Based on Table A8 of ASCE 32, the horizontal extension Dg requirement is 63 inches and the insulation R-value requirement is 10.2. The Commercial Mono Slab EZ Form has an overall R-value of 16.21 and is 24 inches wide. An additional 39 inches of minimum R-10.2 insulation is required to comply with the 63-inch requirement.

Combination of Heated and Unheated Buildings

Residential buildings with both heated and unheated sections are extremely common. The most common example is a heated residence with an unheated garage. Mono Slab EZ Forms may be used for these building types as well. Section 8 in ASCE 32 provides instructions and requirements for small unheated areas within heated buildings and large unheated areas in heated buildings. ASCE 32 requires that each heated and unheated section be regarded as separate buildings. Installation details may be obtained from Mono Slab EZ Form that illustrate how the insulation for the unheated section and the heated section is to be installed. The installer can apply the Mono Slab EZ Forms in the same manner as previously discussed.

Recommendations

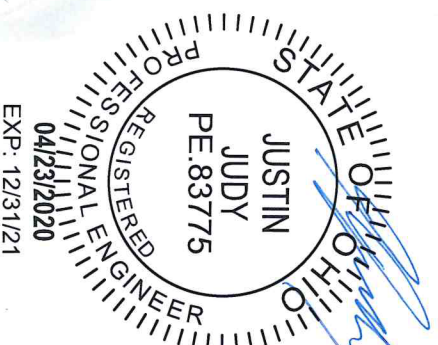
The International Residential Code and ASCE 32 provide very straight forward methods and instructions for properly insulating frost-protected shallow foundations for both heated and unheated buildings as well as other applications. The Mono Slab EZ Forms meet insulation code requirements for frost-protected shallow foundations.

Respectfully,

ENGINEERING SYSTEM SOLUTIONS, ES²



Justin R. Judy, P.E.



Appendix

Mono Slab EZ Form R-values									
X	Arctic			Standard			Commercial		
	Y	R-Value	A*U	Y	R-Value	A*U	Y	R-Value	A*U
0	10.75	19.4	0.0241	8.75	15.8	0.0317	16.75	30.2	0.0124
1									
2									
3									
4									
5									
6									
7									
8									
9									
10	10.6	19.3	0.0017	8.3	15.3	0.0041	11.0	20.7	0.0020
11									
12									
13									
14									
15									
16									
17									
18									
19									
20	10.1	18.6	0.0018	7.4	14.1	0.0044	10.0	18.9	0.0022
21									
22									
23									
24									
25									
26									
27									
28									
29									
30	9.5	17.6	0.0019	6.5	12.5	0.0050	9.0	17.1	0.0024
31									
32									
33									
34									
35									
36									
37									
38									
39									
40	8.9	16.6	0.0020	5.6	10.9	0.0057	8.0	15.3	0.0027
41									
42									
43									
44									
45									
46									
47									
48									
49									
50	8.3	15.5	0.0021	4.7	9.3	0.0068	7.0	13.5	0.0031
51									
52									
53									
54									
55									
56									
57									
58									
59									
60	7.8	14.5	0.0023	3.8	7.6	0.0082	6.0	11.7	0.0036
61									
62									
63									
64									
65									
66									
67									
68									
69									
70	7.2	13.5	0.0025	2.9	6.0	0.0104	5.0	9.9	0.0042
71									
72									
73									
74									
75									
76									
77									
78									
79									
80	6.6	12.4	0.0027	2.0	4.4	0.0142	4.0	8.1	0.0051
81									
82									
83									
84									
85									
86									
87									
88									
89									
90	6.0	11.4	0.0029	9.0	17.1	0.0024	3.0	6.3	0.0066
91									
92									
93									
94									
95									
96									
97									
98									
99									
100	5.5	10.3	0.0032	8.0	15.3	0.0027	2.0	4.5	0.0093
101									
102									
103									
104									
105									
106									
107									
108									
109									
110	4.9	9.3	0.0036	7.0	13.5	0.0031	Overall Horizontal R-Value	Overall Horizontal R-Value	Overall Horizontal R-Value
111									
112									
113									
114									
115									
116									
117									
118									
119									
120	4.3	8.3	0.0040	6.0	11.4	0.0029	12.58	11.05	16.21
121									
122									
123									
124									
125									
126									
127									
128									
129									
130	3.7	7.2	0.0046	5.0	9.9	0.0042			
131									
132									
133									
134									
135									
136									
137									
138									
139									
140	3.2	6.2	0.0054	4.0	8.1	0.0051			
141									
142									
143									
144									
145									
146									
147									
148									
149									
150	2.6	5.2	0.0065	3.0	6.3	0.0066			
151									
152									
153									
154									
155									
156									
157									
158									
159									
160	2.0	4.1	0.0081	2.0	4.5	0.0093			
161									
162									
163									
164									
165									
166									
167									
168									
169									
170	Overall Horizontal R-Value			Overall Horizontal R-Value			Overall Horizontal R-Value		
171	12.58			11.05			16.21		

1. "X" indicates the horizontal inch increments (left to right)
2. "Y" indicates the height of the form at the indicated horizontal position.
3. All values are based on an R-value of 1.8 per inch.

Appendix A: Incremental and Overall R-Values of Mono Slab EZ Forms

